Chapter C5: RUM Analysis

Introduction

Chapter Contents

Cooling water intake structures (CWISs) withdrawing water from the Ohio River impinge and entrain many species sought by recreational anglers. These species include catfish, bass, sunfish, walleye, sauger, perch, and others. Increased fish mortality from I&E in the Ohio River may therefore affect fishing quality at the Ohio River fishing sites and, as a result, the welfare of anglers visiting these sites.

This case study uses a random utility model (RUM) approach to estimate the effects of improved fishing opportunities due to reduced impingement and entrainment (I&E) in the Ohio River. The case study focuses on fishing sites along the following six pools of the Ohio River: Hannibal, Markland, McAlpine, New Cumberland, Pike Island, and Robert C. Byrd. A 120-mile radius buffer zone around these six pools formed the geographic area of the case study. EPA defined this area based on the distances that local anglers are likely to travel to fish the Ohio River for single-day trips. Figure C5-1 depicts the case study area.

The case study relies on the 1994 National Demand Study (NDS) for Water-Based Recreation (U.S. EPA, 1994a) combined with biological data describing fishing conditions in the study area. Only the state of Ohio provided adequate biological data. EPA therefore estimated anglers' behavior with a RUM based on the subset of the NDS sample that includes Ohio anglers only. The Agency then used the model to estimate economic values associated with recreational fishery losses from I&E in the Ohio River as applied to all anglers residing in the study area.

Chapter A10 of Part A provides a detailed description of the RUM methodology used in this analysis. The following sections describe the data set used in the analysis and present analytic results.

C5-1 Data Summary

This section describes the data and supporting analyses required to implement the RUM analysis. The study requires the following general categories of data and supporting analyses:

- information on socioeconomic characteristics of anglers and their preferences (i.e., where they fish and what species they target);
- anglers' choice set of recreational sites, including the sites visited by anglers and substitute sites in their choice sets;
- information on site characteristics that are likely to be important determinants of anglers' behavior; and
- estimated price of visiting the sites.

These four data categories are described below.

C5-1.1 Summary of Anglers' Characteristics

Information on anglers' preferences and characteristics came from the 1994 National Demand Study (NDS) for Water-Based Recreation (U.S. EPA, 1994a). The NDS survey collected data on demographic characteristics and water-based recreation behavior using a nationwide stratified random sample of 13,059 individuals aged 16 and older. EPA used a subset of the NDS sample that includes only single-day trips to sites located in the state of Ohio to estimate the RUM of recreational fishing behavior. As noted above, the Agency did not use observations from other states falling within the case study area in the RUM analysis because only the state of Ohio provided fish abundance data necessary for characterizing fishing sites located along the Ohio River and the relevant substitute sites. The Ohio sub-sample included 909 observations. Of those, 122 took recreational fishing trips. Excluding respondents with missing data on key variables, such as name of the visited water body, home town, and respondents who took multiple day trips results in 74 usable observations.

When estimating the total welfare changes from I&E effects in the Ohio River on the quality of recreational fishing sites, the Agency included all anglers from the 120-mile radius taking both single- and multiple-day trips,. Section C5-6 of this report provides details of this analysis.

Table C5-1 provides descriptive statistics for all anglers residing in the case study area who take single day trips. These data are presented by state to compare characteristics of Ohio's anglers with anglers residing in other states. Table C5-1 shows that anglers' preferences vary only slightly across states, likely making the Ohio subsample used in the RUM analysis representative of all anglers residing in the 120-mile zone. The following paragraphs compare characteristics of Ohio anglers with characteristics of anglers from other states included in the case study area.

A majority of Ohio anglers taking single-day trips (84 percent) prefer to visit lakes or reservoirs. The remaining 16 percent visit streams and rivers. Allocation of fishing trips among water body types is similar in most states included in the study area. The only two notable differences are:

- three to eight percent of anglers from Indiana, Kentucky, and Pennsylvania visit marine water bodies in addition to freshwater bodies
- a majority of anglers in West Virginia (55 percent) prefer to visit streams and rivers.

A majority of Ohio anglers (51 percent) target warmwater species, 46 percent target coldwater species, and the remaining three percent target anadromous species. Ohio anglers' preferences are consistent with angler's preferences from the states of Indiana and Kentucky and are somewhat different from anglers' preferences in Pennsylvania and West Virginia. A majority of anglers from Pennsylvania and West Virginia target coldwater species. However, differences in allocation of target species between Ohio's anglers and Pennsylvania and West Virginia are unlikely to have a significant effect on welfare estimates for two reasons:

- a significant portion of Pennsylvania and West Virginia anglers (25 and 27 percent) target warmwater species; and
- both coldwater (salmon) and warmwater species (e.g., sauger) are affected by I&E in the Ohio River.

Half of the Ohio anglers used either private or rental boats on their fishing trips, compared to between 20 and 40 percent in other states. This difference is likely to stem from the size of water bodies included in anglers choice set. Anglers from Ohio are more likely to visit large water bodies such as Lake Erie or the Ohio River compared to anglers from, for example, Kentucky or West Virginia who might also fish at smaller water bodies where a boat may not be necessary.

On average, anglers in the case study area travel from 31.36 miles to 61.11 mile for a single day trip. The Ohio estimate of 34.63 miles represents a low value.

Table C5-1: Profile of Single-Day Fishing Trips by State

State	N	Allocation of Trips by Water Body Type (% anglers)			Type of Water Fished on Last Trip (% of anglers)				Fished from Boat (% Anglers)	Average Travel distance	Avg Visits	Average Number of Fish Caught
		Lake	Stream	Ocean	Cold	Warm	Salt	Ana-dromous				
IN	40	80%	15%	5%	45%	47%	5%	3%	40%	61.11	7.23	7.13
KY	37	70%	27%	3%	19%	76%	3%	3%	24%	47.97	4.73	6.47
MD[a]	1	NA	0%	0%	NA	0%	0%	0%	0%	NA	NA	NA
NY[a]	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OH	74	84%	16%	0%	46%	51%	0%	3%	47%	34.63	6.91	4.79
PA	38	68%	24%	8%	68%	27%	5%	0%	32%	31.36	4.72	4.94
VA[a]	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
WV	20	45%	55%	0%	75%	25%	0%	0%	20%	36.90	10.20	14.25
Total	210											

[a] NA: no or few sample observations are available for the buffer zone included in the case study. Note that the Agency included NY, MD, and VA counties that fall in the case study area in benefit estimation (see Figure C5-1).

Table C5-2 summarizes socioeconomic characteristics of the sample anglers participating in recreational fishing in Ohio and other states in the case study area. As shown in table C5-2, socioeconomic characteristics of anglers are similar across states included in the case study area. The average annual income of the respondent anglers was between $49,000 and $50,000 in both Ohio and other states.[1] Ninety-three percent of the Ohio anglers are white, with an average age of about 40 years. Anglers from other states are a little bit younger with an average age of about 39.[2] Fewer non white anglers from other states (about two percent)participate in recreational fishing compared to Ohio (about seven percent). Nine percent of the Ohio anglers and eight percent of anglers from other states had not received a high school diploma. Only 23 and 29 percent of anglers from Ohio and other states, respectively, had graduated from college. More than 60 percent of the anglers in all states are males. Twenty seven percent of the anglers in Ohio and 22 percent in other states indicated that they had children aged six and younger. Approximately 54 percent of anglers in Ohio and 50 percent in other states had children aged seven to 16 years.

Table C5-2 shows that on average anglers spent 12.6 days fishing during the past year. Anglers made an average of 6.91 trips to the current site, with an average trip cost of $52.87 (1994$).[3] Average travel time to and from the site was less than 30 minutes.

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[1] Missing income was computed based using a state-specific regression.

[2] This analysis does not include anglers under the age of 16, which may result in an overestimation of the recreational angler's average age.

[3] All costs are in 1994$, representing the1994 survey year. All costs/benefits will be updated to 2000$ later in this analysis (i.e., for welfare estimation).

Table C5-2: Data Summary for Anglers Residing in the Case Study Area

Variable	Number of Observations		Mean Value [a]		Std Dev		Minimum		Maximum	
	Ohio Sample	Other States	Ohio Sample	Other States	Ohio Sample	Other States	Ohio Sample	Other States	Ohio Sample	Other States
Trip Cost	74	NA	$52.87	NA	$72.95	NA	$0.29	NA	$425.27	NA
Travel Time	74	NA	0.33	NA	1.12	NA	0	NA	8.2	NA
Visits	74	137	6.91	6.26	10.05	11.79	1	1	70	100
No High School	74	137	0.09	0.08	0.29	0.27	0	0	1	1
College Degree	74	137	0.23	0.29	0.42	0.15	0	0	1	1
African American	74	137	0.07	0.02	0.25	0.15	0	0	1	1
Age	74	137	40.39	38.88	13.35	13.63	17	16	77	72
Presence of children aged 6 and younger	74	137	0.27	0.23	0.45	0.42	0	0	1	1
Presence of children aged 7 to 16 years	74	137	0.54	0.50	0.50	0.50	0	0	1	1
Household Income	74	137	$49,345	$49,909	$32,352	$31,668	$7,500	$4,999	$150,000	$150,000
Male	74	137	0.66	0.61	0.48	0.49	0	0	1	1
Annual trips	74	137	12.57	11.88	22.76	23.35	1	1	150	230

[a] For dummy variables, such as "male," that take the value of 0 or 1, the reported value represents a portion of the survey respondents possessing the relevant characteristic. For example, 65 percent of the surveyed anglers are males.
NA: Not applicable to anglers from states other than Ohio because EPA estimated travel cost and travel time variables for the site choice model.

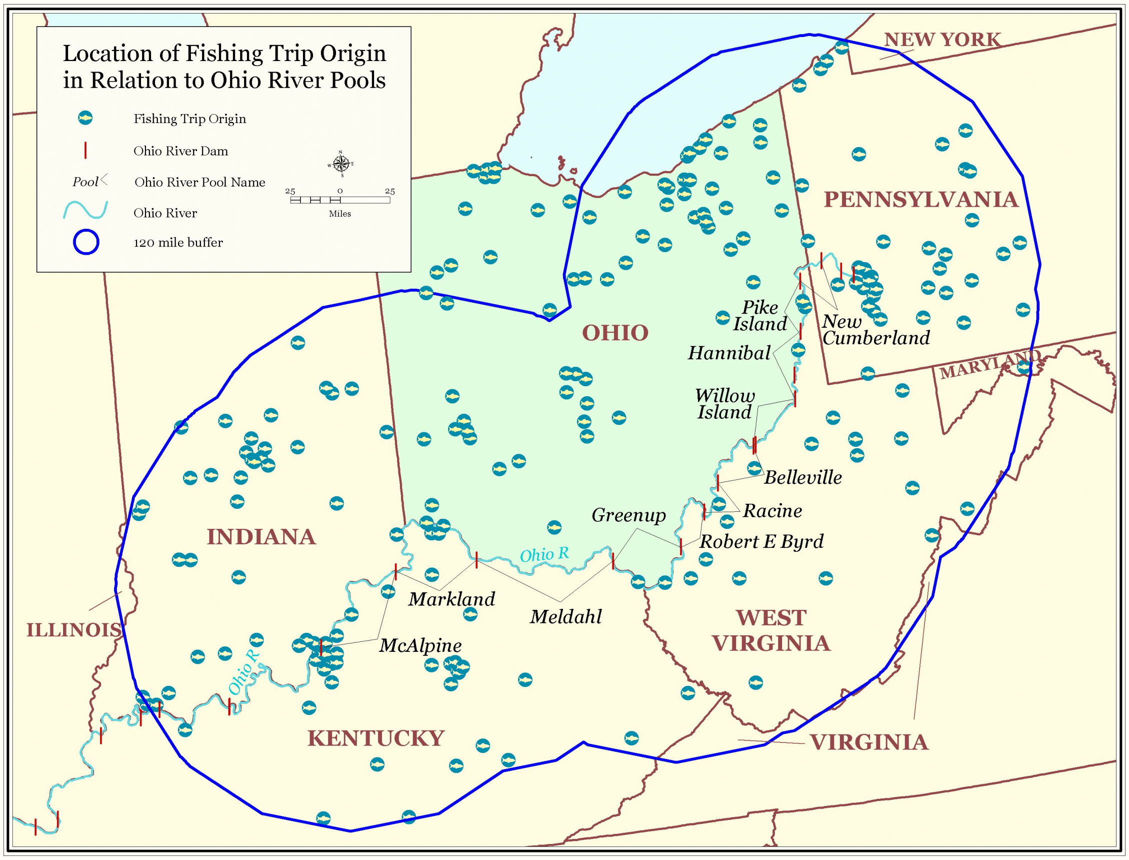
C5-1.2 Recreational Fishing Choice Sets

Figure C5-1 shows the geographic area included in the analysis. To analyze welfare effects from I&E in the Ohio River throughout the study area, the Agency first modeled recreational anglers' behavior in the state of Ohio. As shown in Figure C5-1, most of the Ohio state is included in the case study area. This analysis assumes that Ohio anglers can potentially choose from all water bodies in the state of Ohio. Ohio is a water-rich state, with more than 24,000 miles of named and designated rivers and streams with 451miles bordering on the Ohio River, 200,000 lake and reservoir acres, and about 230 miles of Lake Erie shoreline (Ohio EPA, 1996). Fish are found throughout Ohio in almost every inland surface water body and Lake Erie.

Each consumer choice set theoretically includes hundreds of substitutable recreation sites in Ohio and in the neighboring states. To prevent the recreation site analysis from becoming overly complex, the Agency created randomly-chosen reduced choice sets consisting of 40 recreation sites. EPA then analyzed a sample of recreation sites for each consumer observation. Each participant choice set, by definition, includes the site actually visited by the respondent. EPA drew additional sites for each consumer from a geographic area defined by a distance constraint, using 120 miles as the limit for travel distance used in the analysis. EPA used the resulting aggregate choice set of sites to model angler decisions regarding trip allocation across recreation sites within a 120 mile radius from his home town.

EPA identified recreational fishing sites based on Reach File version 1 (hereafter RF1) and information on recreational fishing areas provided by the Ohio Department of Natural Resources (U.S. EPA, 1997; Ohio Department of Natural Resources; 1996). A recreational fishing site is defined as an RF1 reach or a designated fishing area on an RF1 reach. Ohio has 1144 recreation reaches. These reaches comprise the universal opportunity set. Of these, 580 observations are known recreational sites (e.g., designated fishing areas or parks); 664 observations are RF1 reaches without a known recreational site, and eight observations are neither located in RF1 nor identified as known recreation sites but were visited by an NDS respondent.

Figure C5-1: Ohio River Pools and Fishing Origins



Source: U.S. EPA, 1997.

C5-1.3 Site Attributes

This analysis assumes that the angler chooses among site alternatives based on several observable attributes. The attributes included in this analysis include quality of the fishing site, the type and size of the water body, presence of boat launching facilities, and the site's aesthetic quality. EPA obtained data on site characteristics from three main sources, EPA's RF1; the Ohio Department of Natural Resources (ODNR); and the Ohio Water Resource Inventory (OWRI) database (U.S. EPA, 1997; Ohio Department of Natural Resources, 1996; and OH EPA, 1996).

a. Quality of the fishing site

To specify the fishing quality of the case study sites, EPA used information on relative fish abundance expressed in pounds of fish per 300 meters water body length. Fish abundance is the most important attribute of a fishing site from the anglers' perspective because fish abundance is closely related to catch rate, the most important characteristic of a fishing site from an angler's perspective (McConnell and Strand, 1994). Fish abundance is also a policy variable of concern because fish abundance is directly affected by fish mortality due to I&E. The fish abundance variable in the RUM therefore provides the means to measure baseline losses in I&E and changes in anglers' welfare attributed to changes from I&E due to the 316b rule. In this analysis, EPA used the square-root of fish abundance to ensure the decreasing marginal utility of fish density.

Data on fish abundance came from the OWRI database (OH EPA, 1996). Ohio EPA has operated a systematic monitoring of the state's river, stream, and lake resources since 1980 using biological, chemical and physical assessment tools and indicators. Ohio EPA collected data on various biological measures to support the use of biological indicators in assessing aquatic life use attainment in surface waters. These measures include fish abundance and condition, species richness and composition, and trophic composition. Fish abundance can be characterized by two metrics: the number of individuals per unit distance and fish weight per unit distance (e.g., 300 meters). EPA chose fish weight per unit distance as the most appropriate measure of fish abundance for the Ohio case study because fish weight is a function of both number of fish and fish size. Both factors likely influence how anglers value a recreational fishing site (Ohio EPA, 1996; Ohio EPA, 1988).

Ohio EPA assessed 70, 60, and 42 percent of large, medium, and small rivers and streams, respectively; 64 percent of lakes and reservoirs; and all of the Lake Erie shoreline. EPA used the OWRI fish abundance value for a given site where available. In the absence of observed abundance values, EPA used an Inverse Distance Weighted (IWD) interpolation technique to calculate an average fish abundance for a given fishing site. The IDW technique estimates a value for any given location by assuming that each input value has an influence on that location. This influence diminishes with distance according to a predetermined power parameter. The Agency first located any available fish abundance values within five kilometers from a given fishing site and then used the fish abundance values of the nearest four sites as input values for calculating fish abundance for the site in question. EPA used squared distance values to weight all input values for this calculation.

b. Physical characteristics of the fishing site

Lakes and rivers represent different types of aquatic habitat therefore offer different recreational fishing opportunities to an angler. Physical dimensions of the water body may be also important to an angler for various reasons. For example, smaller water bodies are likely to support fewer fish compared to larger water bodies. Use of boats may be also restricted to non-motorized boats only on small water bodies.

RF1 provided water body type (i.e., lake, river, or reservoir) and physical dimension (i.e., length, width, and depth). The dummy variable, RIVER, characterizes water body type. If a river water body, RIVER takes the value of 1; 0 otherwise. EPA used the logarithm of the reach length LN(REACH SIZE) to define water body size. Water body size data for sites not located in RF1 came from the ODNR (Ohio Department of Natural Resources, 1996).

c. Boat launching facilities

Anglers who own a boat view the presence of a boat ramp as an important factor that may affect their site choice. EPA therefore obtained information on the presence of boat ramps at the study sites from the ODNR, supplemented by the *Ohio Atlas and Gazetteer* (DeLorme, 1995). EPA used a dummy variable (Boat_Ramp=1) for whether or not a site has a boat ramp.

d. Aesthetic quality of the fishing site

Visual appearance of the site may play an important role in an angler's decision to visit a particular site because the site's aesthetic quality will likely affect the angler's recreational trip enjoyment. EPA used ambient concentrations of Total Kjeldahl Nitrogen (TKN) as a proxy for visual water quality at the fishing sites.[4] Excessive nitrogen loading can stimulate or enhance the impact of microscopic algal species and lead to algal blooms.

The study also considers effects of the presence of toxic pollutants on anglers' decisions to visit a particular fishing site. EPA identified Ohio recreation sites at which estimated concentrations of one or more toxic pollutants exceed ambient water quality criteria (AWQC) for aquatic life protection. A dummy variable, AWQC_EX, takes the value of 1 if in-stream concentrations of at least one toxic pollutant exceeds AWQC limits for aquatic life protection, 0 otherwise. This approach accounts for the fact that adverse effects on aquatic habitat are not likely to occur below a certain threshold level.

[4] The relevant data on TKN concentrations come from EPA's water quality database (STORET).

C5-1.4 Travel Cost

EPA used ZipFip software to estimate distances from the household Zip code to each fishing site in the individual opportunity sets.[5][6] As noted above, a fishing site is defined as an RF1 reach or a designated fishing area within a reach. If an RF1 reach has several designated fishing areas, EPA assumed that anglers visited the fishing area nearest to their homes. Otherwise, EPA measured the distance between the household Zip code and the reach midpoint. The program used the closest valid Zip code to match unknown Zip codes. The average one-way distance to a visited site is 42.99 miles.

EPA estimated trip "price" as the sum of travel costs plus the opportunity cost of time following the procedure described in Haab et al. (2000). Based on Parsons and Kealy (1992), this study assumed that time spent "on-site" is constant across sites and can be ignored in the price calculation. To estimate consumers' travel costs, EPA multiplied round-trip distance by average motor vehicle cost per mile ($0.29, 1994 dollars).[7] To estimate the opportunity cost of travel time, EPA first divided round-trip distance by 40 miles per hour to estimate trip time, and then if the angler was employed, multiplied it by the household's wage to yield the opportunity cost of time. EPA estimated household wage by dividing household income by 2,080 (i.e., the number of full-time hours potentially worked per year).

The Agency assumed that employed respondents lost income during the trip (LOSEINC=1). Employed respondents are assigned a time cost in the trip cost variable. Approximately 73 percent of the survey respondents were assumed to lose income. EPA calculated visit price for employed anglers as:

$$\textit{Visit Price} = \textit{Round Trip Distance} \ x \ \$.29 + \frac{\textit{Round Trip Distance}}{40 \ \textit{mph}} \ x \ \textit{Wage} \qquad \textit{If LOSEINC} = 1 \tag{C5-1}$$

EPA assumed that respondents who are retired, unemployed, or homemakers do not lose income during the trip (LOSEINC=0). Visit price for retired, unemployed or homemakers was calculated as follows:

$$\textit{Visit Price} = \textit{Round Trip Distance} \ x \ \$.29 \qquad \textit{If LOSEINC} = 0 \tag{C5-2}$$

For those respondents who did not lose income during the trip (LOSEINC=0), EPA used an additional variable equal to the amount of time spent on travel. EPA estimated travel time as the round-trip distance divided by 40 mph:

$$\textit{Travel Time} = \begin{array}{ll} \textit{Round Trip Distance}/40 & \textit{If LOSEINC} = 0 \\ 0 & \textit{If LOSEINC} = 1 \end{array} \tag{C5-3}$$

The Agency used a log-linear ordinary least square regression model to estimate wage rates for the 20 percent of the survey respondents who did not report their income. This regression is described in Chapter B5 of this document. The average imputed household income is $42,183 per year and the corresponding hourly wage is $13.94.

C5-2 Site Choice Models

EPA used a RUM, described in Chapter A10 of Part A, to estimate anglers' site choices. The model assumes that the individual angler makes a choice among mutually exclusive site alternatives based on the attributes of those alternatives. EPA identified anglers' choice sets based on a travel distance constraint (Parsons, 1997). All fishing sites within a 120 mile radius from the angler's hometown are eligible for inclusion in the angler's choice set. Individual choices may include hundreds of sites. To prevent the model from becoming overly complex, EPA estimated the site choice model using the site actually visited and 39 randomly drawn sites within the choice set area for each Ohio angler.

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[5] The program was created by Daniel Hellerstam and is available through the USDA at http://usda.maunlib.cornell.edu/datasets/general/93014.

[6] Note that EPA estimated distances to all recreation sites in the consumer's opportunity set. The Agency used a random draw from the opportunity set for the purpose of estimating the model parameters but estimated the inclusive value using all recreation sites in the consumer's opportunity set.

[7] EPA used the 1994 government rate ($0.29) for travel reimbursement to estimate travel costs per mile traveled. This estimate includes vehicle operating cost only.

An angler's choice of sites relies on utility maximization Maddala, 1983; McFadden 1981). An angler will choose site *j* if the utility (u_j) from visiting site *j* is greater than that from vising other sites (*h*), such that:

$$u_j > u_h \qquad for\ h = 1,\ \ldots\ J\ and\ h \neq j \tag{C5-4}$$

Recreational fishing models generally assume that anglers first choose a fishing mode (i.e., boat or shore) and species (e.g., warmwater and coldwater), and then a site. Instead of incorporating the angler's decision regarding the mode of fishing and target species in the model, the Agency assumed that the mode/species choice is exogenous to the model and the angler simply chooses the site. EPA used the following general model to specify the deterministic part of the utility function:[8]

$$v_j = f\,(TC_j,\ TT_j,\ RAMP_j,\ Ln(RCHSZE_j),\ RIVER,\ \sqrt{GWGT_j},\ \sqrt{RWGT_j},\ TKN_j,\ AWQC\_EX_j) \tag{C5-5}$$

where:

v_j	=	the expected utility for site *j* (j=1,...40);
TC_j	=	travel cost at site j;
TT_j	=	travel time for survey respondents who don't receive wages;
$RAMP_j$	=	presence of a boat ramp at site *j*;
$Ln(RCHSZE)_j$	=	the logarithm of the reach length;
$RIVER_j$	=	a dummy variable that takes the value of 1 if the water body is a river; 0 otherwise;
$SQRT(GWGT_j)$	=	square root of relative fish abundance (pounds per 300 meters) at site *j* on Lake Erie;
$SQRT(RWGT_j)$	=	square root of relative fish abundance (pounds per 300 meters) at site *j* on river reaches*;*
TKN_j	=	ambient concentrations of TKN at site j; and
$AWQC\_EX_j$	=	a dummy variable that takes the value of 1 if in-stream concentrations of at least one toxic pollutant exceed its threshold value for aquatic life protection, 0 otherwise.

Table C5-3 gives the parameter estimates for this model.

Table C5-3: Estimated Coefficients for the Conditional Site Choice

Variable	Estimated Coefficient	t-statistics
TRAVEL COST	-0.0463	-21.530
TRAVEL TIME	-0.4015	-3.886
RAMP	1.5976	13.138
RIVER	-0.9219	-3.953
LN (RCHSZE)	0.5793	6.858
SQRT (RWGT)	0.0681	2.385
SQRT (GWGT)	0.2649	5.150
TKN	-0.1194	-1.005
AWQC_EX	-0.2431	-1.548

Table C5-3 shows that most coefficients have the expected signs and are statistically significant at the 95th percentile. Travel cost and travel time have a negative effect on the probability of selecting a site, indicating that anglers prefer to visit sites closer to their homes (other things being equal). A positive coefficient on the boat ramp indicates that anglers owning a boat are more likely to choose sites with a boat ramp. A positive coefficient on the reach size variable shows that anglers are more likely to visit larger water bodies. The river variable coefficient is negative, indicating that anglers are likely to prefer the Great Lakes or inland lakes. The model shows that anglers prefer sites with more fish and cleaner water, all else being equal.

[8] See Chapter A10 of Part A for details on model specification.

The probability of a site visit increases as relative fish abundance increases because catch rate, the most important site characteristic from an angler's perspective, is a function of fish abundance and angler's experience. The greater coefficient on the Great Lakes fish abundance variable (SQRT(GWGT)) compared to the river fish abundance variable (SQRT(RWGT)) indicates that anglers value Great Lakes fishery more than inland fishery. Poor water quality has a negative impact on an angler's decision to visit a particular site. Higher ambient concentrations of TKN in surface water have a significant negative effect on the probability of site selection. This is not surprising, since elevated nutrient concentrations are indicative of potential eutrophication problems, which may lead to a foul smell in surface water and unattractive visual effects. This variable's insignificant coefficient is likely due to the correlation between the presence of nutrients and that of toxic pollutants in surface water. The presence of toxic pollutants also has a negative effect on anglers' choices of fishing sites. The AWQC_EX variable coefficient is significant at the 88th percentile only.[9]

C5-3 Trip Participation Model

EPA also examined effects of changes in fishing circumstances on an individual's choice concerning the number of trips to take during a recreation season. EPA used the negative binomial form of the Poisson regression model to estimate the number of fishing trips per recreational season (Parsons et al., 1999; Feather et al, 1995; Hausman et al., 1995). The participation model relies on socioeconomic data and estimates of individual utility (the inclusive value) derived from the site choice model. This section discusses results from the Poisson model of recreational fishing participation, including statistical and theoretical implications of the model. A detailed discussion of the Poisson model is presented in Chapter A10 of Part A.

The dependent variable, the number of recreational trips within the past 12 months, is an integer value ranging from one to 200. The Agency first tested the Ohio data on the number of fishing trips for overdispersion to determine whether to use the negative binomial form of the Poisson model. The Poisson model is appropriate if the dispersion parameter is equal to zero; otherwise the negative binomial is more appropriate (Winkelmann, 2000). The analysis found that the overdispersion parameter (α) is significantly different from zero and therefore the negative binomial model is the most appropriate for this case study.

Independent variables of importance include age, ethnicity, gender, education, and the number of children in different age groups in the household. Variable definitions for the trip participation model are:

- IVBASE: an inclusive value estimated using the coefficients obtained from the site choice model;
- NOHS: equals 1 if the individual did not complete high school, 0 otherwise;
- COLLEGE: equals 1 if the individual completed college, 0 otherwise;
- AGE: individual's age in years. If not reported, the individual's age is set to the sample mean;
- MALE: equals 1 if the individual is a male, 0 otherwise;
- MALE_KIDS: equals 1 if the individual is a male and has kids, 0 otherwise;
- FEM_KIDS: equals 1 if the individual is a female and has kids, 0 otherwise; and
- α (alpha): overdispersion parameter estimated by the negative binomial model.

Table C5-4 presents the results of the trip participation model. All parameter estimates in the participation model have the expected signs. Five of the eight parameters (IVBASE, AGE, FEM_KIDS, COLLEGE, and α) differ significantly from zero at the 85th to 95th percentile. The remaining three parameters (MALE, MALE_KIDS, and NOHS) do not differ significantly from zero. The following paragraphs discuss each variable in greater detail.

[9] Alternative model specifications that included a different variable representing fish population at a given site (e.g., number of fish per 300 meters or index of well being (IWB) resulted in a negative and significant (at the 95th percentile) effect associated with the AWQC_EX variable.

Table C5-4: Trip Participation Model (Negative Binomial Model)

Variable	Coefficient	t-statistics
IVBASE	0.148	1.708
NOHS	0.308	0.555
COLLEGE	−0.789	−1.468
AGE	0.289	2.282
MALE	0.456	0.967
MALE_KIDS	0.119	0.243
FEM_KIDS	0.726	2.936
Overdispersion Parameter		
α (alpha)	0.827	5.437

The positive coefficient on the inclusive value index (IVBASE) indicates that the quality of recreational fishing sites has a positive effect on the number of fishing trips per recreational season. EPA therefore expects improvements in recreational fishing opportunities, such as an increase in fish abundance and catch rate, to result in an increase in the number of fishing trips to the affected sites. The magnitude of the estimated coefficient, however, indicates that changes in fishing participation in response to improvements in recreational fishing quality will be modest.

The model shows that education is likely to influence trip frequency. The NOHS variable coefficient is positive, but not significant, indicating that people who did not complete high school and those with a high school diploma are equally likely to participate in recreational fishing. Conversely, the COLLEGE variable coefficient is negative and significant at the 85th percentile, indicating that respondents who attended college are less likely to participate in fishing than those who have only a high school education.

The AGE variable coefficient is positive and significant, indicating that older people are likely to take more fishing trips. A positive but insignificant coefficient for the MALE variable indicates that males and females are equally likely to participate in fishing activities. This result is somewhat counterintuitive. An insignificant sign on this variable is likely to be caused by two over-influential observations. Two female respondents reported the largest number of trips (100 and 150) in the Ohio sample. EPA attempted to correct the effect of over-influential observations by setting the maximum number of fishing trips per season to 90 in the fishing participation model. This correction did not affect the significance of the MALE variable.

The presence of children in the household has different effects on fishing participation for males and females. Females with children are more likely to participate in fishing activities. This result is not surprising, because mothers are more likely to provide transportation for their children and to participate in their activities. Conversely, the presence of children in the household does not have a significant effect on a male's participation in recreational fishing.

The coefficient on the dispersion parameter alpha (α) is significantly different from zero, indicating the negative binomial form is the most appropriate for this analysis.

C5-4 Welfare Estimates

This section presents estimates of welfare losses to recreational anglers from fish mortality due to I&E, and potential welfare gains from improvements in fishing opportunities due to reduced fish mortality stemming from the §316b rule.

C5-4.1 Estimating Changes in the Quality of Fishing Sites

The Agency estimated effects of I&E in the Ohio River on the quality of recreational fishing sites under different policy scenarios in terms of changes in relative fish abundance within each of the six pools included in the study. EPA used estimates of the losses to recreational fisheries based on I&E of the relevant fish species, as described in Chapter C3 of this document, to estimate changes in total fish biomass in a given pool from reducing I&E. Assuming that fish abundance is uniform within each pool, changes in relative fish abundance under different policy scenarios can be calculated as follows:

$$\Delta \ Fish\ Weight\ per\ 300\ m = \frac{Fishery\ \ Losses}{Pool\ \ Length}\ x\ 300\ m \qquad (C5\text{-}6)$$

where:

Δ Fish Weight per 300 m =estimated change in relative fish abundance in lbs per 300 m;
Fishery Losses = estimated losses to recreational fishery lbs per year;
Pool Length = pool length in meters; and
300 m = unit distance used in calculating relative fish abundance (meters).

Table C5-5 presents results of this analysis for each of the six pools.

Table C5-5: Estimated Changes in Fishery Yield from Eliminating all I&E in the Ohio River

Estimated Fishery Loss to I&E (pounds of fish)						Estimated Change in Fish Abundance from Eliminating I&E (lbs per 300 m)	
Pool	Pool Size (meters)	Pounds of Fish Impinged		Pounds of Fish Entrained		All Phase 2 Facilities	All Facilities
		Phase 2	All	Phase 2	All		
Hannibal	73,700	100	116	1,228	1,432	5.40	6.30
Markland	164,785	3,042	3,087	13,493	13,689	30.10	30.54
McAlpine	126,554	9,331	9,486	5,540	5,632	35.25	35.84
New Cumberland	38,664	1,302	1,372	767	809	16.05	16.92
Pike Island	50,198	684	836	1,170	1,430	11.08	13.54
Robert C. Byrd	70,685	538	543	16,814	16,951	73.65	74.25
Total	**NA**	**14,998**	**15,439**	**39,012**	**39,942**	**NA**	**NA**

C5-4.2 Estimating Losses from I&E in the Ohio River

The recreational behavior model described in the preceding sections provides a means for estimating the economic effects of recreational fishery losses from I&E in the Ohio River. First, EPA estimated the welfare gain to recreational anglers from eliminating fishery losses due to I&E. This estimate represents economic damages to recreational anglers from I&E of recreational fish species in the Ohio River under the baseline scenario.

EPA estimated anglers' willingness to pay for improvements in the quality of recreational fishing due to I&E elimination by first calculating an average seasonal welfare loss per angler and then multiplying it by the total number of anglers residing in the 120-mile buffer zone. The Agency calculated the average seasonal welfare loss to an Ohio angler from I&E effects in the Ohio River based on the subsample of 65 Ohio anglers residing within 120 miles of the Ohio River.[10] This analysis assumes the estimated average welfare loss to an Ohio angler is representative of the welfare loss to anglers residing in other states included in the study area.

To estimate per trip seasonal welfare losses to an angler residing in the study area, the Agency combined the estimated model coefficients with the estimated changes in relative fish biomass from eliminating I&E at the CWIS located in the six pools of the Ohio River. Individual estimates were then averaged across 65 Ohio anglers residing in the 120-mile zone. Table C5-6 presents the estimated welfare loss per trip and per season (averaged over the Ohio anglers residing in the 120-mile zone) associated with I&E of recreational species. The estimated economic value of recreational fishery losses from I&E at the 43 CWIS located in the case study is $0.12 per trip or $1.24 per recreation season. EPA also estimated that the economic value of recreational fishery losses from I&E at the 29 Phase 2 CWIS is $0.12 per trip or $1.21 per recreation season.

[10] EPA used a sample of 74 Ohio anglers to analyze recreational anglers' behavior.

Table C5-6: Per Trip and Seasonal Welfare Gain Associated with Eliminating I&E in the Ohio River

Policy Scenario	Per Trip Welfare Gain (2000$)	Seasonal Welfare Gain (2000$)	Percentage Increase in number of Trips
Eliminating I&E at All Phase 2 CWIS	$0.12	$1.21	0.04%
Eliminating I&E at All CWIS	$0.12	$1.24	0.04%

EPA calculated the total damages to recreational anglers from I&E in the Ohio River by combining the estimated seasonal welfare loss to an angler with the total number of recreational anglers residing in the buffer zone. The Agency based its estimate of the total number of anglers who can potentially travel to the Ohio River fishing sites on the total adult population residing within the 120 mile buffer zone and the percent of adult population participating in recreational fishing as follows:

- First, EPA estimated the resident population in the 120-mile buffer zone using the U.S. Census Bureau (2000). The Agency included population block groups in the study area based on whether or not the block group centroid fell within the buffer zone. EPA then estimated the number of individuals aged 16 and older in the spatially-selected block groups to get the total eligible population within the buffer zone for a given state.

- Then, EPA estimated the state-specific percent of the population participating in recreational fishing based on the NDS data.

- Finally, EPA estimated the total number of anglers residing within the 120-mile buffer zone for each state by multiplying the relevant resident population by the state-specific percent of the population engaged in recreational fishing and then summing over state specific estimates.

Table C5-7 presents the results of this calculation.

As shown in Table C5-7, between 13 and 33 percent of recreational anglers take multiple-day trips.. EPA determined the single- and multiple-day splits based on the proportion of single-day trips in the NDS sample used for the Ohio River case study. EPA estimated welfare changes to multiple-day anglers based on the estimated welfare changes to single-day anglers and a simple linear extrapolation technique. The Agency assumed that per day welfare gain from improved fishing site quality is independent of trip length. EPA therefore adjusted seasonal welfare change for multiple-day anglers by multiplying the seasonal welfare change estimated for single-day anglers by the average number of days per multiple-day trip. Table C5-8 provides an average trip length for multiple day trips by state.

Table C5-7: Recreational Fishing Participation in the Ohio River Zone by State and by Duration

State	Number of Fishing Trips By State and Duration			
	Total Anglers	Single Day	Multiple Day	
		% of Total	% of Total	Avg. Trip Length (days)
IL	1,109	74.7%	25.3%	6.74
IN	696,421	81.3%	18.7%	4.00
KY	727,501	77.8%	22.2%	4.00
MD	17,144	86.3%	13.7%	5.71
NY	3,967	77.0%	23.0%	7.62
OH	1,476,133	77.3%	22.7%	4.37
PA	656,757	73.4%	26.6%	3.88
VA	14,702	67.0%	33.0%	4.39
WV	328,944	79.3%	20.7%	3.67
Total	3,922,678			

EPA calculated the economic values of recreational losses from I&E in the Ohio River by multiplying the estimated seasonal welfare losses for each type of angler (e.g., single-day and multiple-day) by the number of anglers in each trip category residing in the 120-mile buffer zone. The estimated recreational losses (2000$) to recreational anglers from I&E in the Ohio River at all Phase 2 facilities and all facilities in the study area are $8.06 and $8.23 million, respectively. Table C5-8 presents results of these calculations.

Table C5-8: Welfare Losses Associated with I&E at the Ohio River CWIS

Policy Scenario	Welfare Estimates (2000$)
Baseline Welfare Losses from all CWIS in the Ohio River	$8,232,491
Baseline Welfare Losses from the Phase 2 CWIS	$8,059,275

C5-4.3 Estimating Fishery Losses from I&E for Individual Pools in the Ohio River

The Agency also estimated losses to recreational anglers from I&E in each of six pools of the Ohio River. EPA calculated pool-specific losses by first estimating the percentage of the total recreational losses (pounds of fish) from I&E in the Ohio River attributed to a given pool and then applying the estimated percentage to the estimated welfare loss from I&E in the Ohio River. Table C5-9 presents calculation results by pool and by the type of environmental effect (i.e., impingement vs. entrainment). Table C5-9 shows that recreational losses from I&E at the Ohio River CWIS vary significantly across six pools. The estimated I&E losses at the in-scope CWIS range from $0.2 million for the Hannibal pool to $2.6 million for the Robert C. Byrd pool. Table C5-9 also shows that total entrainment losses ($5.9 million) are more than two-and-a-half times higher than the total impingement losses ($2.3 million). For some pools (e.g., New Cumberland and McAlpine), however, the value of impingement losses exceeds the value of entrainment losses.

Table C5-9: Welfare Losses from I&E in the Ohio River by Pool (2000$)

Pool	Losses from I&E at All Phase 2 In-Scope CWIS			Losses from I&E at All CWIS in the Ohio River		
	Impingement	Entrainment	I & E	Impingement	Entrainment	I & E
Hannibal	$14,884	$183,208	$198,091	$17,291	$212,837	$230,128
Markland	$453,995	$2,013,362	$2,467,357	$458,859	$2,034,936	$2,493,795
McAlpine	$1,392,371	$826,650	$2,219,021	$1,410,046	$837,143	$2,247,189
New Cumberland	$194,262	$114,489	$308,751	$203,925	$120,184	$324,108
Pike Island	$102,115	$174,614	$276,729	$124,269	$212,497	$336,767
Robert C Byrd	$80,335	$2,508,991	$2,589,326	$80,682	$2,519,822	$2,600,504
Total	$2,237,962	$5,821,313	$8,059,275	$2,295,072	$5,937,419	$8,232,491

C5-5 Limitations and Uncertainties

C5-5.1 Considering Only Recreational Values

This RUM study understates the total benefits of improvements in fishing site quality because estimates are limited to recreation benefits. Other forms of benefits, such as habitat values for a variety of species such as freshwater drum, minnows, and American eel(in addition to recreational fish) are also likely to be important.

C5-5.2 Modeling

a. Multiple-day trips

This analysis did not use a model specifically for multiple-day trips, which yielded an insufficient number of observations. EPA instead used linear extrapolation from single-day trip estimates to evaluate multiple-day trips. This extrapolation may either over- or understate benefit estimates, but the degree of error is likely to be insignificant because the majority of fishing trips fall into the single-day trip category.

b. Model assumptions

The model necessarily assumes that trips are independent choice occasions because it uses data for the latest fishing trip for each angler to predict behavior. The model does not account for the fact that choices regarding trips across a season or year might be correlated.

C5-5.3 Data

The geographic distribution of sample observations used in the analysis of anglers' behavior is likely to result in underestimation of benefits from reduced I&E in the Ohio River. As shown in Figure C5-1, most of the Ohio fishing trips originated from locations remote from the Ohio River. Because travel distance has a negative impact on site selection, improvements in remote fishing sites are likely to have a lower value to anglers, other things being equal. Conversely, most fishing trips in other states included in the case study originated from the areas that are in close proximity to the Ohio River. If observations from other case study states that fall into the 120-mile zone were included in the model, anglers' benefits from improvements in the Ohio River fishery would likely be larger. In addition, substitute sites in Ohio include Lake Erie reaches that attract many anglers (see Sections C5-1.1 and C5-4). The presence of prominent recreational sites in close proximity to an angler's home town will likely diminish the value of other sites. The Ohio River is the largest close water body for many anglers residing in other case study states; these anglers may therefore assign more value to the Ohio River fishery.

C5-5.4 Potential Sources of Survey Bias

a. Recall bias

Recall bias can occur when respondents are asked, such as in the NDS survey, the number of their recreation days over the previous season. Avid participants tend to overstate the number of recreation days because they count days in a "typical" week and then multiply them by the number of weeks in the recreation season. For this reason, some researchers believe that recall bias tends to lead to the number of recreation days being overstated. More avid participants often neglect to consider days missed due to bad weather, illness, travel, or when fulfilling "atypical" obligations. Some studies also found that the more salient the activity, the more "optimistic" the respondent tends to be in estimating the number of recreation days. Individuals also have a tendency to overstate the number of days they participate in activities that they enjoy and value. Taken together, these sources of recall bias may result in an overstatement of the actual number of recreation days.

b. Sampling effects

Recreational demand studies frequently face observations that do not fit general recreation patterns, such as observations of avid participants. These participants can be problematic because they claim to participate in an activity an inordinate number of times. This reported level of activity is sometimes correct but sometimes overstated, perhaps due to recall bias. These observations tend to be overly influential even when the reports are correct.